Abstract: The Irrigation Association and the American Society of Irrigation Consultants have developed the Landscape Irrigation Best Management Practices for irrigation professionals and policy makers who must preserve and extend the water supply while protecting water quality. The BMPs will aid key stakeholders (policy makers, water purveyors, designers, installation and maintenance contractors, and consumers) to develop and implement appropriate codes and standards for effective water stewardship.
The following professionals provided valuable contributions to the document during 2013:

Luis Andrade, CLIA, Ewing, Houston, Texas
Chris Butts, Georgia Green Industry Association, Epworth, Georgia
Baine Carruthers, QLM, Inc., Gastonia, North Carolina
Matt Cline, CIC, Teacher’s Landscaping & Irrigation, Olathe, Kansas
Stephen Geckeler, CLIA, Aqua-Lawn, Fairfield, Connecticut
Mel Grills, Mr. Lawn Irrigation, Greenwood, Missouri
Deville Hubbard, Hadden Landscaping, Plano, Texas
John Moore, California Landscape Contractors Association, Sacramento, California
Theodore J. Moriarty, CIC, CID, CLIA, Smart Watering Company, West Roxbury, Massachusetts
Ivy Munson, ASIC, The I.S.C. Group, Inc., Livermore, California
John J. Newlin, CIC, CLIA, Quality Sprinkling Systems, Inc., North Ridgeville, Ohio
Jon Peters, Baseline, Inc., Boise, Idaho
Brian E. Vinchesi, ASIC, CID, CIC, CLIA, CGIA, CLIM, CLWM, Irrigation Consulting Inc., Pepperell, Massachusetts

The following professionals provided review and input during 2013:

Allan Schildknecht, CID, Irrigation Hawaii, Ltd., Kaneohe, Hawaii
William Smillie, Landscape Water Management, Nipomo, California
Scott Sommerfeld, East Bay Municipal Utility District, Oakland, California

Acknowledgements:

Contact Information:

Irrigation Association
6540 Arlington Blvd.
Falls Church, VA 22042
Tel: 703.563.7080
Fax: 703.536.7019
www.irrigation.org

American Society of Irrigation Consultants
4660 South Hagadorn Road, Suite 110F
East Lansing, MI 48823
Tel: 508.763.8140
Fax: 866.828.5174
www.asic.org
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Foreword

The Irrigation Association (IA) and American Society of Irrigation Consultants (ASIC) have developed these landscape irrigation best management practices (BMP) to promote efficient use of water in the managed landscape. Primary stakeholders include water purveyors, system owners, irrigation consultants, irrigation designers, contractors, water managers and maintenance personnel. Additional stakeholders include state, federal and public agencies, code developers, and related landscape industries and associations. This document provides required information that is comprehensive and specific while allowing for local adaptation.

Managed landscapes, while highly visible users of water, provide ecological, economical and recreational benefits. It is the stakeholders’ responsibility to advocate for efficient irrigation and to incorporate and promote all reasonable practices that minimize water consumption. The broad and comprehensive nature of the best management practices and related practice guidelines define the elements of an efficient irrigation system and responsible water management. Specific benefits include:

- Enjoining the water purveyor and the landscape and irrigation industries in water planning and development of local strategies to manage irrigation water use.
- Improving irrigation efficiency to optimize water use.
- Reducing energy costs of treating and pumping water.
- Providing performance-based criteria to achieve desired results that fit the purpose and function of the managed landscape.

The Landscape Irrigation Best Management Practices document includes:

- Three best management practices that address the design, installation and management of irrigation systems.
- Practice guidelines that address ways to effectively implement the respective BMPs and can be adapted locally.
- Appendices that provide useful information for the implementation of the BMPs.

The tools provided herein are meant to help ensure the design, installation and management of efficient irrigation systems. The BMPs and related practice guidelines provide the basis for sensible, informed decision making regarding regional water use and potential response to drought.

As professionals engaged in making decisions about how water is used, it is important to consciously seek to evolve fundamental attitudes and values to better serve the community.

John W. Ossa, CID, CLIA
Chairman, Landscape Irrigation BMP Task Group
Section 1: Introduction

1.1 Purpose
The primary purpose of a landscape irrigation system is to provide supplemental water when rainfall is not sufficient to maintain the turfgrass and plant materials to meet their intended purpose. A quality irrigation system and its proper management are required to efficiently distribute supplemental water in a way that adequately maintains plant health while conserving and protecting water resources and the environment. Assuring the overall quality of the system requires attention to system design, installation, and management. In particular, this includes the following:

- The irrigation system shall be designed to efficiently deliver water to the landscape.
- The irrigation system shall be installed according to the irrigation design specifications.
- The irrigation system shall be managed to maintain a healthy and functional landscape while conserving and protecting water resources.

1.2 Definitions

1.2.1 Landscape Irrigation Best Management Practice
Landscape irrigation best management practices improve water use efficiency, protect water quality and are sensitive to the watershed and environment. Landscape irrigation BMPs are economical, practical and sustainable, and they will maintain a healthy, functional landscape without exceeding the minimum water requirements of the plants.

1.2.2 Practice Guidelines
Practice guidelines (PG) are recommended practices or principles that aid in successfully accomplishing the related BMP. The PG is meant to be a guide to develop criteria that address site-specific landscape irrigation needs. It is the responsibility of the framers of such specifications to adapt the guidelines to meet their local needs.

1.3 Stakeholders
The primary stakeholders that benefit from the best management practices and practice guidelines include water purveyors and owners of the irrigation system, irrigation consultants, irrigation designers, irrigation contractors, water managers and landscape maintenance personnel. Additional stakeholders include state, federal and public agencies, code developers, landscape contractors, nurseries, related landscape industries and associations. Refer to appendix A for a list of stakeholders and the issues that each must confront to achieve improved resource conservation.
1.4 Qualified Professionals

The implementation of best management practices and practice guidelines requires a commitment from qualified irrigation professionals. “Qualified” includes being formally trained, certified, licensed where required, having successful experience completing projects of similar scope, or other similar qualifications that meet state and local requirements. IA certifies individuals in design, contracting, and management of irrigation systems. The ASIC recognizes Professional Irrigation Consultants (PIC) as irrigation professionals who have been peer reviewed and board approved for the design and management of irrigation systems.

The BMPs as described in this document recognize there are other licensing and certifying organizations in the irrigation industry but these programs stand on their own merit and were not evaluated for this document.

A listing of certified individuals can be found on IA’s web site at http://www.irrigation.org.

A listing of Professional Irrigation Consultants can be found on the ASIC web site at http://www.asic.org.

There may also be regionally appropriate certifications.
Section 2: Landscape Irrigation Best Management Practices

To assure the overall quality of the irrigation system and that irrigation efficiency is achieved, the following best management practices need to be implemented.

BMP 1: Design the Irrigation System for Water Use Efficiency

The irrigation system shall be designed to precisely distribute supplemental water as efficiently as possible regardless of its source and meet the design intent of the landscape plan and water budget. The design intent and how the irrigation system is intended to be installed shall be clearly shown on the drawings.

BMP 2: Install the Irrigation System to Meet the Design Criteria

The irrigation system shall be assembled and installed according to the irrigation design, details, specifications and manufacturer’s product requirements. The qualified irrigation contractor or installer shall be capable of quality workmanship, knowledgeable in the safe use of proper equipment, and familiar with applicable local code requirements.

BMP 3: Manage Landscape Water Resources

To conserve and protect water resources within local watersheds, the management of the irrigation system will maximize the efficient use of available water resources to maintain a healthy and functional landscape with optimal irrigation system performance. Management includes active irrigation maintenance, evaluation of the system, scheduling, and monitoring of water use and landscape plant materials.
Section 3: Practice Guidelines

All water resources are important and these practice guidelines will hold true for projects that use municipally supplied water as well as on-site developed water resources. Vital to water efficient design and management is a plant palette that is appropriate to the region. Knowledgeable landscape water management must focus on how the soil and irrigation work together creating the foundation for a healthy landscape. Not all of the listed guidelines will be implemented on each site, but the landscape water manager needs to be aware of the ones that have specific application.

PG 1: Practice Guidelines for Designing an Irrigation System

Practice Guidelines can be used to develop site-specific irrigation plans, details and specifications while optimizing system design efficiency. Implementation of these guidelines is best done as a collaborative effort between practitioners and the authority holding jurisdiction to meet local conditions and while maintaining a viable and functioning landscape. The inclusion of these practice guidelines shall be compatible with state and local regulations, codes and ordinances.

To ensure that the irrigation system is designed to efficiently apply water and to conserve and protect water resources, the qualified irrigation designer or irrigation consultant shall perform a project analysis and site inventory as part of the information gathering phase.

Items to be included in the project analysis:

- Site-specific needs/constraints
- Need for temporary systems
- Level of commitment to system management
- Irrigation window/time constraints
- Product type preferences
- Project budget
- Project phasing

"Qualified" means being formally trained, certified, licensed, and having successful experience completing similar type projects or other similar qualification that meets state and local requirements.

Items to be included in the site inventory:

- Available site utilities (water, electrical, etc.)
- Quality characteristics of water sources
- Alternative water source(s)
- Local water purveyor information/restrictions
- Local water conservation guidelines and regulations
- Understanding of the landscape design intent
The irrigation consultant/designer should supply an irrigation design package to the owner of the system documenting site-specific information used in the design calculations.

**Minimum Plan Requirements**
- The graphic presentation of the diagrammatic design shall include clear and concise reproducible drawings with all components sized, symbolized and keyed in a distinctive manner.
- Drawings are to be at a suitable scale to be clearly legible and have a north arrow.
- Sheet sizes are to match whole package documentation.
- Complete installation details shall accompany the drawings. Details to be project specific.
- Written specifications shall supplement the drawings detailing materials and workmanship to be used in the installation. Specifications shall be project specific.
- Designs shall comply with plumbing and electrical codes and all federal, state and local regulations including landscape codes/ordinances addressing water use efficiency.
- The system management intent is to be clearly communicated in the design package, including a drought management plan where appropriate.

**Plan Submittal**
When required, a complete plan package including the design, details and specifications shall be submitted to the appropriate governing agency for approval prior to installation of the system. Typically, the irrigation consultant submits plans to the client for package submittal with a landscape design.

"A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise."

Aldo Leopold
_A Sand County Almanac, 1948_
The Irrigation Design Package shall include the following:

1. **Basis of design**

   1.1 **Identification**
   
   a. Include statement or narrative that identifies the assumptions used for design purposes such as: water sources to be used, total landscape water demand based on area, effective rainfall, water window, assumed irrigation efficiency and energy constraints for system operation.
   
   b. Confirm the irrigation design plan accounts for local water laws, permitting requirements and applicable codes.
   
   c. Convey how the system should be operated to use water resources efficiently to achieve the desired function of the landscape.

   1.2 **Calculations**
   
   a. Estimate water requirement.
      1) Identify the peak water demand month during the growing season (greatest reference ET and least rainfall).
      2) Estimate plant-water requirement for each hydrozone by modifying the reference ET with appropriate plant factors that consider the functional purpose and aesthetic quality intended. Sum the total water need for each hydrozone to calculate the landscape water requirement.
      3) Where water budgets are used, verify that the landscape water requirement is less than the landscape water allowance or allotment including expected irrigation efficiency.
      4) If the water requirement is greater than the allowance, consult with the landscape architect or designer to make landscape modifications or adjust plant performance expectations within specific hydrozones.
      5) Estimate any leaching fraction needed when a lower quality water source is used.
   
   b. Establish water window and frequency.
      1) Reasonable water windows should be less than 10 hours during normal conditions (see discussion below).
      2) Irrigation frequency should be appropriate for the climate, soil type and plants used in the landscape.
      3) Water source, size and pressure and/or pump sizing must be considered.
         - If the water source and point of connection (POC) already exist, determine the water window that will be needed to meet peak demand.
         - For new water connections the water window is used to determine the required capacity of the water tap or POC.
      4) Comply with local watering restrictions.

   1.3 **Recommendations**
   
   a. Use an expected irrigation efficiency of 75 or 80 percent for appropriate calculations.
   
   b. Consider future needs such as expansion of the system to accommodate further development.
2. **Site-specific information**

2.1 Identification

a. Weather considerations
   1) Historical temperature and rainfall data
   2) Prevailing wind direction and speed

b. Physical features
   1) Site grading and drainage plans
   2) On-site water bodies/water features
   3) Conservation, utility or right-of-way easements, etc.
   4) Building, parking lots, roadways and other structures
   5) Walkways, patios and other secondary hardscape features
   6) Exterior lighting plan when available
   7) Location of site utilities when available

c. Hydrozone areas
   1) Soil type (e.g., clay, loam, sand, etc.) and soil profile if applicable
   2) Exposure: sun/part shade/full shade — consider seasonal variation
   3) Reflected light and/or heat from adjacent building or hardscape
   4) Plant materials
      • Type of turfgrass
      • Annual color/bedding plants
      • Herbaceous perennials
      • Ground cover
      • Shrubs/woody plants
      • Desert or drought tolerant plants
      • Trees
   5) Sloped areas/topography
   6) Special situations, such as building overhangs, on-structure planting, areas of deep shade, raised planters, supplemental watering, etc.

2.2 Minimum design requirements

a. Provide separate irrigation zones to meet unique water requirements for each identified hydrozone.

2.3 Recommendations

a. Note if special trenching or installation techniques are required.

b. Identify heritage trees or special features.

c. Consult with landscape designer to identify more efficient water-use strategies in the landscape.

*Intent:* The irrigation system shall be designed to facilitate efficient installation and the long-term maintenance of the system as the landscape matures. Where systems are to provide a temporary plant establishment service or are for a specific function such as leaching, hardware appropriate to that function and longevity requirement shall be selected.
2.4 Calculations
   a. Designed flow rate (gpm) and operating pressure for each irrigation zone.
   b. Designed precipitation rate for each zone.
   c. Area/square footage of each irrigation zone.
   d. Estimated water use for each hydrozone/peak month usage.
   e. Minutes of run time to supply peak month water demand for each zone.
   f. Minutes of run time to apply leaching fraction to mitigate water quality issues when applicable.
   g. Total minutes of run time to water window for peak month comparison.

3. Select water sources for the irrigation system

3.1 Identification
   a. Consider all sources of legally available water on-site that can be used for irrigation and will help minimize the amount of potable water to be used for irrigation.
      1) On-site developed water
         • Rainwater harvesting
         • Storm water capture
         • Graywater
         • Process water
         • Foundation water
         • Air-conditioning condensate
      2) Municipally reclaimed water (abide by local codes and constraints)
      3) Groundwater
      4) Surface water such as lakes, streams, rivers or canals
      5) Potable water supply
      6) Identify class of contaminant in water supply (e.g. particulate, biological, chemical)
      7) Other
   b. Show source of water and POC for irrigation system.
      1) Exact location/address of each POC specifying water source/type.
      2) Type, size and length of meter service piping.
      3) Meter type and size.
      4) Static pressure and available flow.
      5) Pump station or booster pump location and performance requirements (flow and pressure) when required.
      6) In freezing climates, provide a method to winterize the system.
   c. Dedicated irrigation-only meters and flow sensors (sizes and locations).
   d. Backflow prevention assemblies (type, size and location).
      1) Downstream of POC on potable water service.
      2) Locate in non turfgrass areas where possible and accessible for servicing.
      3) Protect the backflow assembly from vandalism or theft.
      4) Protect the backflow assembly from freezing where necessary.
3.2 Calculations
   a. For municipal water supplies, calculate maximum safe flow rate.
      1) The maximum allowable pressure loss through the meter should be less than 10 percent of the static pressure at the meter.
      2) The maximum flow rate through the meter should not exceed 75 percent of the maximum safe flow through the meter (refer to charts for the specific type of meter).
      3) The velocity of the water through the service line supplying the meter should not exceed 7.5 feet per second.
   b. For on-site developed water sources.
      1) Calculate reliable yield for all available water sources.
      2) Determine storage capacity for the water sources to match climatic conditions.
      3) Match available water and storage with water requirements.

3.3 Recommendations
   a. Comply with all state and local laws regarding alternate water sources.
   b. Use lowest acceptable quality of water and supplement with higher quality of water when necessary.
   c. Assure water quality will not harm plant growth and development prior to specifying its use.
   d. Provide cost-benefit analysis for using alternate water sources and help the owner make an informed decision.

4. Irrigation components

4.1 Identification
   a. Zone valves sizes and locations
   b. The site area (location/hydrozone) served by each valve
   c. Pipe layout including sizes, main line and lateral
   d. Sprinkler head location nozzle size and spray pattern (full, half, quarter, etc.)
   e. Controller(s) and location(s)
   f. Sensor types and their locations
      1) Weather sensors such as solar radiation, temperature, rain, and/or freeze sensors.
      2) Soil moisture sensors
      3) Flow sensors
   g. Drip/microirrigation devices
      1) Drip valve, pressure regulator, filter assembly.
      2) Supply/exhaust manifold location.
      3) Flush plugs and/or air/vacuum relief valves.
      4) Emitter flow rate and spacing if using inline drip tubing.
      5) Tubing depth.
      6) Lateral row spacing.

4.2 Design requirements
   a. Use symbols indicating the location of the various irrigation components.
   b. Specify manufacturer, model, type and size of all components.
   c. Develop a key of the symbols to facilitate plan reading.
   d. Provide specific installation details for all components.
   e. Provide written site-specifications for the project including general conditions.
5. **Sprinkler head selection and spacing**

5.1 **Identification**
   a. Select specific sprinkler heads and nozzles to apply water uniformly to the target area.
   b. Select products suitable to the landscape requirements.
   c. Select products to facilitate long-term reliability and serviceability.
   d. Select products that are compatible with the quality of the proposed water source.

5.2 **Calculations**
   a. Calculate the precipitation/application rate of the sprinklers for each zone.
   b. For turfgrass areas, specify a low quarter distribution uniformity (DU_{LQ}) based upon size and geometry of the area.

5.3 **Minimum design requirements**
   a. Do not exceed manufacturer’s sprinkler spacing recommendations.
   b. Design system so sprinklers operate within manufacturer-recommended operating pressure.
   c. Use matched precipitation rate sprinklers (+/- 5 percent) within a zone.
   d. Design system with no overspray of hard surface areas that will cause runoff of water from the site.
   e. Space sprinklers a minimum of 2 inches from hard surface edges.
   f. Specify a pop-up height of the sprinkler to clear interference from vegetation.
   g. Include protective covers/lids specifically designed for use on athletic fields for sprinklers in “play” areas such as athletic fields.
   h. Include purple markings on sprinklers and valves when using municipally reclaimed water sources.
   i. Design the system to avoid or eliminate low-head drainage.
   j. Use pop-up type sprinklers/shrub bubblers near pedestrian walkways, bicycle paths, etc.

5.4 **Recommendations**
   a. If pressure exceeds equipment recommended operating range, use pressure-regulating valves, sprinklers or nozzles to optimize performance.
   b. Use lower precipitation rate sprinklers on slopes or heavy soils to reduce runoff potential.
   c. Use check valves to control low-head drainage.
   d. In areas of high vandalism use vandal-resistant products and parts to minimize potential damage or theft of the sprinklers.

6. **Valves and Valve Boxes**

6.1 **Identification**
   a. Zone/station control valves
   b. Manual isolation valves
   c. Pressure-regulating valves
   d. Specialty valves
      1) Pressure relief valves
      2) Air release valves
3) Quick coupling valves
4) Drain/flush valves
5) Strainers and filters

6.2 Calculations
a. Designate an acceptable operating pressure range (minimum to maximum) in pounds per square inch.
b. Calculate the flow rate for each zone control valve.

6.3 Minimum design requirements
a. Install valves to accommodate identified hydrozones.
b. Size the zone control valve so that flow through the valve is within the manufacturer’s stated flow range and so that pressure loss does not exceed 10 percent of static pressure.
c. Use fittings off the main line so that the valve aligns on the same horizontal plane as the lateral piping.
d. Install valves either above grade or below grade in a valve box large enough to service or access.
e. Keep valve boxes out of athletic fields or recreation areas where they may interfere with use or aesthetics of the area.
f. Use valve boxes colored purple when using municipally reclaimed water or as applicable by code.
g. Install the valve and valve box over a layer of coarse stone or gravel for stability and drainage.

6.4 Recommendations
a. Install a master valve on larger systems. When pressure is excessive (greater than 15 percent above recommended operating pressure), the following equipment could be used:
   1) Pressure-reducing valve(s) at point of connection.
   2) Pressure-regulating device that can be added to the zone control valve.
b. Specify zone control valves with flow control.
c. Specify fittings to allow for the easy removal of the remote control valve for servicing if necessary.
d. Use isolation valves on larger systems to facilitate servicing.
e. Install chemigation or fertigation equipment downstream of an approved backflow prevention assembly.

7. Pipes and fittings

7.1 Identification
a. Type of pipe to be used for main lines and laterals lines.
   1) Polyvinyl chloride (PVC) polyethylene (PE), high-density polyethylene (HDPE) or other
   2) Pipe classification shall be indicated on plan key and specifications.
   3) The pipe shall be clearly marked with the manufacturer, size, schedule and/or pressure rating.
b. Colored pipe shall be used when required by code.
   1) Purple pipe for reclaimed or alternate water sources.
   2) Brown pipe for aboveground installation usually on steep slopes.
c. Minimum size for each pipe section.
e. Type of fittings to be used for main lines and for laterals.
f. Type of swing joint to be used with each type of sprinkler head.

7.2 Calculations

a. Pressure loss for the “worst-case” zone. This may be the largest zone and/or the farthest zone from the POC and/or the zone with the greatest elevation change.
b. Flow in plastic pipe operating at full system capacity.
   1) Velocity shall not exceed 5 feet per second.
   2) Pressure variation within a zone should have less than 10 percent variation.
   3) Surge pressures in the main line shall be less than the safety factor of the piping.

7.3 Minimum design requirements

a. Piping
   1) The working pressure rating of the mainline pipe should be a minimum of 200 psi or at least twice the anticipated design pressure of the system, whichever is greater.
   2) Mainline piping should be sized to optimize pressure/flow conditions and should have the same pressure rating throughout.
   3) Lateral pipes should have a pressure rating at least two times the operating pressure of the sprinklers.
   4) Lateral piping should be sized to minimize pressure losses and optimize flow conditions.
b. Depth of pipe bury
   1) The minimum depth of soil cover shall conform to local codes and/or as shown or listed in the drawings, details or specifications. When pipe bury is not listed on the plan, the generally accepted practice for pipe bury is the following:

<table>
<thead>
<tr>
<th>Minimum cover measured from the top of pipe (or as specified)</th>
<th>Main line</th>
<th>Lateral lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>12 inches</td>
<td>8 inches</td>
</tr>
<tr>
<td>Commercial</td>
<td>18 inches</td>
<td>12 inches</td>
</tr>
<tr>
<td>Under vehicular paving</td>
<td>24 inches</td>
<td>24 inches</td>
</tr>
</tbody>
</table>

2) Backfill around pipe shall not have rocks or debris greater than ½-inch in size next to the pipe.

c. Fittings
   1) Pipe fittings and connections shall be suitable for the exposure, pressure and flow applications.
   2) The fittings shall be compatible with the type of pipe and the operating pressure of the system.
   3) Gasketed fittings on mainline piping shall have restraints or thrust blocking.
   4) HDPE fittings that are fusion or socket joined shall have the same dimension ratio (DR) as the pipe.
   5) Fittings for PE pipe shall be insert-type or compression-type, suitable for the size and pressure rating of the system and using suitable clamps when required.
   6) Threaded PVC pipe shall be Schedule 80 or better.
7.4 Recommendations
   a. Piping
      1) In pipe sizes 4 inches and larger, maximum pipe velocities should be less than 4 feet
         per second.
   b. Sleeving
      1) Under vehicular paving, pipe shall be installed in a sleeve made of a permanent rigid
         material (e.g., PVC at least Schedule 40 or Class 160, whichever is strongest).
         - Sleeving should be twice the size of the piping or wiring bundle that it will hold (2-
           inch pipe in a 4-inch sleeve and wires that fit in a 1-inch conduit shall have a 2-inch
           sleeve).
         - It should extend a minimum of 2 feet beyond the edge of hard surfaces.
         - Subject to local authority holding jurisdiction.
         - Pipe and wire shall be in separate conduits.
         - Conduits should be laid parallel, not stacked, to facilitate future service with
           horizontal separation between the conduits.
      2) Pipe sleeves should be marked for future location.
   c. Fittings
      1) Fittings for PVC
         - Fittings 4 inches and larger shall be gasketed fittings, preferably ductile iron.
         - Fittings 3 inches shall be gasketed or solvent welded.
      2) For PE pipe, worm gear clamps shall be used exclusively in sizes 1½-inch and larger.
      3) Connection to sprinklers.
         - Use of adjustable multidirectional connection or flexible swing pipe assembly under
           sprinklers that are less than 4 gpm is permitted.
         - For sprinklers with a flow rate greater than 4 gpm, use swing joints that are made
           with rigid piping and multiple elbows/street ells to allow for multidirectional
           adjustment.

8. Drip/Microirrigation

8.1 Identification
   a. Statement of intent
      1) Identify if system is intended as a permanent system to establish, maintain and provide
         supplemental irrigation to meet plant-water requirement or a temporary system for
         plant establishment, after which it is to be abandoned. State what period of time
         constitutes “plant establishment.”
   b. For design purposes, identify the soil type.
   c. Consider if primary movement of water through the target root zone will be by gravity or
      capillarity.
   d. Identify emitter types for various hydrozones.
      1) Specify pressure-compensated emission devices to improve overall uniformity.
      2) Identify flow rate and operating pressures.
8.2 Calculations
   a. The system should be capable of meeting the maximum daily water requirement for the mature plant size. The water delivery rate should be proportional to the plant type and size.
      1) Precipitation rate per zone.
      2) Monthly maximum/minimum zone run times based on local historical ET.
      3) Plant establishment maximum/minimum run times based on local historical ET.
      4) MAD factor (management allowed depletion).

8.3 Minimum design requirements
   a. Separate drip/microirrigation zones where distribution hardware is surface mounted from subsurface zones.
   b. Separate microspray irrigation zones from other emitter types.
   c. Ensure adequate sizing and layout of mains and sub mains to accommodate irrigation events and provide adequate system maintenance flush velocity. Avoid any dead ends that cannot be flushed.
   d. Piping
      1) Systems shall be looped (where practical) to improve system uniformity and mitigate possible contamination of tubing if system is damaged.
      2) On slopes, run the tubing on contour to the slope to keep each run of the tubing at approximately the same elevation.
      3) For line-source systems, expand row spacing over approximately the lower third of a slope. Conversely, compress row spacing at the top of the slope.
      4) Specify trench filling and compaction method for subsurface drip irrigation installation.
   f. Emitter placement
      1) For line-source drip irrigation, provide emitter and row spacing guidelines based on soil type and site conditions.
      2) For subsurface line-source drip irrigation, provide guidelines for location of subsurface drip irrigation laterals from hardscape edges and uncontained landscape areas.
      3) For point-source emitter systems, emission points to new plants should be located midway between the edge of the root ball and the crown of the plant.
      4) For permanent drip irrigation systems, provide sufficient emitters located in the desired mature root zone area to wet at least 70 percent of the mature root zone. Provide isolation valves to separate drip lines used for establishment from those to be used for long-term maintenance. On slopes, locate the majority of emission points on the upslope side of the plant crown.
      5) Where soil texture, tilth or slope are likely to induce runoff, provide for mini-basins to mitigate runoff.
   e. Pressure regulation
      1) Pressure shall be regulated to the manufacturer’s recommended range for distribution hardware.
      2) Pressure regulation devices shall be sized for the design flow rate of the irrigated zone and should accommodate flow rates during system flush.
   f. Filtration
1) Identify class of system contaminant: particulate, organic or chemical.
2) If filtration element is a screen filter, specify mesh size and equivalent micron rating.
3) If filtration element is a disk filter, specify mesh size and equivalent micron rating.
4) If filtration is by media filter, identify media sand sizes and their micron equivalent.
5) Identify acceptable pressure loss through filter and threshold for maintenance event.

g. **Flush valves**
   1) Install flush valve in a valve box.
   2) Follow the manufacturer recommendation for maximum system size per flush valve.
   3) Ensure adequate flow is available to remove contaminant during flush/back flush as appropriate.
      - Suggested flushing velocity for potable water is 1 foot per second.
      - Suggested flushing velocity for nonpotable water is 2 feet per second.

h. **Air/vacuum relief and check valves**
   1) Use air/vacuum relief valves to minimize ingestion of contaminants into distribution hardware.
      - All laterals within the elevated area shall be connected with an air relief valve except for emitters that incorporate a check valve and meet manufacturer requirements for proper operation.
   2) Follow manufacturer recommendation for maximum system size per air relief valve.
   3) Determine air vent sizing by the operating flow rate for relatively flat sites.
   4) Determine air vent sizing in accordance to the maximum drainage flow rate for sites with slopes and varied topography.
   5) Install check valves in the headers and footers to mitigate lateral drainage to the low point if not included in the emitter device; accompany the check valve with an air relief valve at the highest location within the (sub) section of the zone.

**8.4 Recommendations**

a. Consider differing plant-water requirements, root zone-depths and slope. Use separate drip/microirrigation zones where practical.

b. When using nonpotable water, consider recommending installation of chemigation/fertigation system to address tubing/emitter maintenance.

c. Recommend the use of the same emitter type and output within a zone.

d. Recommend a fitting at the flush valve to accommodate a pressure gauge.

e. **Management strategies**
   1) Recommend the installation of a water meter or flow sensor, where possible, to capture data for management purposes.
   2) Recommend a controller with capability of multiple start times or cycle/soak feature to deliver pulse irrigation for establishing and sustaining a wetted pattern as well as achieving optimum irrigation efficiency.
   3) Identify vertebrate and insect control strategy.
   4) When required, identify strategy to manage soil salinity.

f. **Special considerations for subsurface drip irrigation (SDI)**
   1) For seeded areas, provide guidelines for the use temporary overhead spray to augment seed germination such as maximum/minimum spray duration.
   2) For sod, provide guidelines for ensuring adequate soil moisture in advance of sod installation.
- Provide guidelines for use of spray (minimum/maximum run times) and time period that temporary spray shall be deployed to ensure sod establishment.

3) For trees and shrubs it may be necessary to place tubing (permanently or temporarily) on top of rootballs during establishment to hydrate root ball.

4) It is recommended to establish system maintenance protocols, especially where non-potable water is used.

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**Water Quality Assessment**

Water Quality – Irrigation water should be assessed to determine its suitability for irrigation. This is done in order to recommend water treatment when required. The assessment should identify the chemical characteristics of the water and address possible problems with soil salinity and plant health caused by the use of the water. The following table includes water quality tests to be completed before designing or installing a system when non-potable water sources are considered for use.

<table>
<thead>
<tr>
<th></th>
<th>Units</th>
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<th>Moderate</th>
<th>High</th>
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<td>Hydrogen Sulfide (H₂S)</td>
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<td>Manganese (Mn)</td>
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<td>10,000-50,000</td>
<td>&gt;50,000</td>
</tr>
</tbody>
</table>

Adapted from Hanson et.al, 1994 and Hassan, 1998
9. **Controllers and wire**

9.1 Identification

a. Controllers shall list manufacturer, model number, and station count and how it will be installed in the field.
b. Wiring shall identify the gauge of wire and insulation rating for underground installation.
c. Coverage depth for wires
   1) Wires and cables carrying up to 30 volts shall be installed with a minimum of 12 inches of cover.
   2) For irrigation controller output cables carrying more than 30 volts (such as decoder-to-solenoid) and where the controller is UL-listed as a “Power Limited Power Source” (Class 2 or Class 3), minimum depth of burial is 12 inches.
   3) For wires and cables carrying more than 30 volts and less than 600 volts, follow local and national codes.

9.2 Minimum design requirements

a. Controllers
   1) Specify the location of the controller(s) on the plans.
   2) Specify any required sensors.
   3) Ensure the controller features meet the minimum requirements of EPA WaterSense® program such as multiple start times, multiple programs, sensor inputs, lithium battery to retain programs during power outages, etc.

b. Wiring
   1) All underground wires shall be insulated copper conductors and UL-listed for direct burial.
      - Low voltage wiring (less than 30 volt) to control valves shall be type PE or type UF.
      - Gauge of wire shall meet manufacturer’s recommendations depending on length of run.
      - Wiring for two-wire systems shall be specifically manufactured for the control system being used.
      - Use of decoder-to-solenoid cable (paired multicolored wires in a single cable) may be appropriate on two-wire systems.
   2) Wires must be installed to allow for expansion and contraction, using
      - “Snaking” the wire.
      - Wire loops at bends.
      - Expansion coils at connections or at the solenoid valve location.
   3) Electrical connections
      - All electrical connections shall incorporate a solid mechanical connection of the copper conductors using a UL-listed device and a waterproof kit for electrical insulation of the mechanical connection. Connector assemblies shall be listed under UL 486D.
      - Grounding, when required, shall follow the detailed plan, manufacturer’s recommendation, and local and national codes.
9.3 Recommendations
a. Controllers
   1) Use controllers that incorporate sensors to override or suspend irrigation when irrigation is not required, that can adjust scheduled irrigation to meet site needs, and/or that can be monitored remotely.
   2) Use controllers that can send alarms or notify the water manager of flow problems in the field.
   3) When selecting a controller that has two-way communication such as internet access consider units that track and report levels of water conservation as compared to budgeted/planned conservation levels.
b. Wiring
   1) Wire splices should be in valve boxes so they can be readily located.
   2) Wire shall be in electrical conduit using sweep ells when installed into the controller location. If the controller location is at a low point, ensure adequate drainage of the conduit and pull boxes.
   3) Wireless sensors (rain, soil moisture, flow, etc.) shall follow manufacturer’s recommendations for proper operation and installation.

Sensors
   1) Rain, freeze, and/or wind sensors to suspend irrigation during weather conditions that are unfavorable for irrigation.
   2) Soil moisture sensors will monitor soil moisture and can suspend or initiate irrigation depending on the soil moisture conditions. A separate common wire from the controller to each hydrozone type will provide flexibility in the use of sensors to manage the irrigation system.
PG 2: Practice Guideline for Installing an Irrigation System

A qualified irrigation contractor shall be selected to install the irrigation system based on the requirements of PG 2. The irrigation contractor shall test the completed system to verify that the system operates according to the design criteria.

The following practice guideline helps meet the requirements of BMP 2. PG 2 intends to facilitate the development of minimum requirements and expectations for the proper installation of an efficient irrigation system. The successful implementation of these guidelines is best done as a collaborative effort between practitioners, property owners and governing agencies to meet local conditions and circumstances that will protect the watershed while maintaining a viable and functioning managed landscape. The means, methods, and outcomes derived from these guidelines should seek to be economical, practical, and sustainable.

The contractor shall adhere to the following:

1. Prior to installation

   1.1 Contact all appropriate utility companies prior to beginning installation to locate underground utilities including gas lines, electrical, telephone, cable TV, and so forth. Installation shall not start until all underground utilities are located and marked.
   a. The contractor/installer shall coordinate with the property owner to locate, identify and mark all privately owned underground utilities.
   b. The following free notification services are available: call 811 or www.call811.com.

   1.2 Prior to beginning installation, verify that the water sources, various points of connection (including pump stations), flow rate, and static and dynamic pressures meet design criteria. If there is a discrepancy, notify the irrigation designer to make irrigation design modifications.

   1.3 Review irrigation plans and actual site conditions prior to installation. Provide submittals where required by plans and specifications. Substitution of materials must be pre-approved prior to usage. Inform the designer of conflicts and obstacles not shown on design (such as hardscape features, plantings, utility boxes, etc.) and review possible solutions.

   1.4 Obtain any required permits prior to beginning the installation.

2. During installation

   2.1 Irrigation systems shall be installed in a manner conforming to the irrigation design plans and specifications, the design intent, applicable codes and standards, in conformance to the manufacturer's installation instructions.

   2.2 Avoid disturbing and damaging existing trees, shrubs, and other plant material including root systems from construction and installation activities.

   2.3 Inform the property owner or his/her representative and irrigation designer of unusual or abnormal soil conditions that may impact the design and management of the irrigation system.
2.4 Ensure sediment and erosion control measures are included in the scope of work.
2.5 Make all necessary final sprinkler adjustments to avoid unwanted overspray and to ensure sprinklers are precisely set to water only the target areas.
2.6 Ensure all sprinklers and valve boxes are set to proper grade

3. Following installation

3.1 Furnish a legible “red-line” record set of drawings to the owner of the system or, where required, the system designer. Within the record set of drawings, describe the system layout and components including all changes from the original design.

3.2 Test the irrigation system to verify the operating pressure and ensure that there are no leaks and components are adjusted correctly to meet the design criteria.

3.3 Program the irrigation controller with the irrigation schedule that will meet the landscape water requirement for the current time of year. The schedule will take into account site conditions and will mitigate runoff. Post the controller settings so they can be used for review and reference.

3.4 Explain to the end user (owner, owner representative, or landscape maintenance personnel) the location and operation of the controller, valves, sensors, pressure regulators, backflow device, sprinkler heads, and drip/microirrigation devices. Inform the owner of features and capabilities of the system and furnish product literature, warranties, or operating manuals.

3.5 Provide the end user (or owner) with recommendations for irrigation system maintenance.
   a. Maintaining proper operation of system components.
   b. Winterization procedures (including spring start-up) where applicable.
   c. Testing of backflow prevention assembly per local code.
d. Periodic visual inspection of the system while operating:
   1) Leaks
   2) Missing or broken components
   3) Sprinklers out of adjustment
   4) Drip irrigation filter and flush valve
   5) Others
Effective landscape water management is how landscape and irrigation professionals demonstrate responsible stewardship of resources. The purpose for having an irrigation system is to support the health and viability of the managed landscape by delivering supplemental water to the plants when natural precipitation is not adequate. The irrigation skills and horticultural knowledge required for implementation of best practices come from proper training, experience, and continuous monitoring of the soil-water-plant relationship.

The following guidelines cover the key elements of landscape water management: communication, system maintenance, water budgeting, irrigation scheduling, monitoring and evaluation of water use, irrigation system performance, and landscape health and function. All of these elements are interdependent. Water efficient landscapes are created by appropriate design and installation, but landscape water management and maintenance are what produce and ensure desired results.

The Art & Science of Water Management
Water management can be as simple as turning the water off, but maximizing the potential of a landscape while reducing its water use can be complex. The correct amount of water can be quantified — it is science-based. Proper management, however, is both a science and an art. A skilled water manager has in-depth knowledge of multiple disciplines and may utilize advanced technology to improve water use efficiency.

The Management-Maintenance Connection
Proactive system maintenance will ensure the integrity of the irrigation system. As the landscape matures, and plants mature, the system may require adjustment and enhancement to meet the design intent for the landscape. System maintenance and repair shall seek to support site management objectives. Depending on company structure, one person, or many individuals, may be qualified to perform multiple management functions.
1. **Communication and accountability**

The water manager, property owner and landscape maintenance personnel need to work together to achieve the desired results.

1.1 **Communication among key players**

   a. Property owner/agent should ensure a loop of communication exists with the industry professionals to implement proper site and water management.

   b. Property owner/agent and the landscape water manager should engage the water purveyor as a resource. The water purveyor may provide rebates, system evaluations, and water efficiency and conservation initiatives.

   c. **Recommendations:**

      1) Establish a regular interval to review contract performance and resource use.
      2) Authorize an amount of money that can be spent to perform unforeseen repairs.
      3) Provide the landscape water manager access to water bills and records for each project.
      4) Develop a drought/water shortage contingency plan.

1.2 **Landscape water manager responsibilities**

   a. **Communication**

      1) Water manager shall advise and educate field personnel on their role in managing resources and meeting the owner’s expectations (see Monitoring section).
      2) Coordinate maintenance activities that will affect water-use efficiency.
      3) Determine who has authorization to make changes to the system, the irrigation schedule and emergency service calls.

   b. **Documentation**

      1) Establish a record keeping system.
         - Track weather conditions
         - Track water usage
         - Track system maintenance activities (see Maintenance section).
      2) Perform on-site observations/verify existing conditions (see Evaluation section).
      3) Identify quantitative and qualitative metrics for the site.
      4) Identify and understand special conditions
         - Site usage (special events, maintenance activities, etc.).
         - Water source and new water sources.
         - Drought/water shortage conditions.

   c. **Calculations**

      1) Estimate site water usage (see Water Budgeting section).
2) Develop irrigation schedules (see Scheduling section).
3) Develop a system maintenance budget for owner approval.

d. Recommendations:
1) Utilize technology
   • Technology helps the manager do a more thorough and complete job.
   • Online/internet-based technology allows for more rapid response to problems.
2) On a new site design, feedback with the designer may be beneficial to improve overall efficiency.

1.3 Outcomes of communication tools
a. Accountability of stewardship
   1) Is the correct amount of water being used?
   2) Is the site in compliance with any watering restrictions?
   3) Are other resources being used wisely?

b. Relationship and trust
   1) Increased communication among key parties.
   2) Improved corporate image for both owner and contractor.

c. Preserve assets in cost-effective strategy
   1) Healthy and vibrant landscapes.
   2) Reduction of hardscape maintenance requirements.
      • For example, parking lots, sidewalks, roadways, fencing, etc.

2. Maintenance
Regular and routine maintenance of the irrigation system is best accomplished if directed by the irrigation manager to assure that the system operates optimally. The maintenance schedule will ensure that the proper equipment is used and a plan to respond to unforeseen problems such as vandalism can keep the system working well and minimize wasted water.

2.1 Initial steps
a. Establish a periodic and routine maintenance schedule to inspect and report performance conditions of the irrigation system to the end-user/owner/owner’s representative.

b. Create a station/zone map for ease of system inspection and controller programming. In the absence of an as-built or record drawing, include the location of key components such as controllers, main shutoff valve, isolation valves, remote control valves, filters and any sensors or decoders.

2.2 Periodic maintenance
a. Review the system components periodically (i.e. annually or as determined by the water manager) to verify the system functionality:

b. Inspect and verify that the backflow prevention device is working correctly and have it tested as required.
c. Inspect and verify that the water supply and pressure meet system operational requirements for optimal system efficiency.

d. Adjust valves for proper flow, closing speed, and operation as needed.

e. Inspect and verify pressure regulators are properly set and adjusted (if installed).

f. Test system wiring for continuity and integrity, and document readings.

g. Establish a “winterization” protocol (if required based on climate) and a corresponding process for system activation in the spring.

2.3 Ongoing maintenance

a. Review the system components regularly (i.e. weekly) to verify the efficient operation and uniform distribution of water:

1) Examine and clean filtration as needed.

2) Inspect and verify proper operation of the controller. Confirm correct date/time input and functional backup battery where used.

3) Inspect and verify that sensors used in the irrigation system are working properly.

4) Inspect and verify that sprinkler heads are operating at recommended pressures and are properly adjusted — nozzle size, arc, radius, level and attitude with respect to slope.

5) Ensure that plant material is not blocking or interfering with the operation or output of sprinkler heads.

6) Inspect drip irrigation zones, check the pressure regulator, service the filter and flush laterals to remove silt and foreign matter. Inspect for clogged and missing emitters or damage to the tubing and make repairs.

7) Repair or replace broken pipe or malfunctioning components and restore the system to its optimal performance capabilities.

8) Test and adjust all repairs.

• Complete repairs in a timely manner to support the integrity of the irrigation system.

b. Ensure that replacement parts will perform the same as original equipment.

1) Sprinklers or nozzles used for system repairs will maintain matched precipitation rate within the hydrozone.

2) Valves will have the required performance features to meet site conditions such as flow requirements, pressure, and water quality.

3) Document maintenance procedures and findings.
2.4 Additional considerations
a. A thorough maintenance program will extend the useful life of the irrigation system.
b. Good horticultural practices and irrigation management are needed to sustain the efficient use of water.
c. Changes and modifications to the irrigation system will be necessary as the landscape matures.

3. Budgeting
Water budgeting as a landscape water management tool allows the water manager to plan or anticipate the amount of water required to maintain a healthy and functional landscape. The water budgeting process includes calculating a landscape water allowance and estimating the landscape water requirement.

The allowance is based on historical reference evapotranspiration data usually for a growing season and can be normalized for real-time weather conditions as the season progresses. The total landscape water requirement is based upon calculating the water requirement for each type of hydrozone in the landscape and summing the water requirement of all hydrozones. The water requirement is based on real-time weather conditions. The manager can utilize meter readings to compare the amount of water applied based on the irrigation scheduling to the water requirements. Adjustments can be made to the schedule as necessary to maintain an acceptable plant appearance within the water allowance. Measured water usage is compared to both the landscape water requirement and the landscape water allowance.

3.1 Landscape water allowance
a. Following is a general formula for calculating a landscape water budget (LWA) for any time period:

\[ \text{LWA} = \text{ET}_\circ \times \text{AF} \times \text{LA} \times 0.623 \times \text{LF} \]

where

- \( \text{LWA} \) = landscape water allowance \{gallons of water\}
- \( \text{ET}_\circ \) = evapotranspiration for the time period, either reference ET or historical average ET \{in.\}
- \( \text{AF} \) = an ET adjustment factor
  - Normally ≤ 1.0, reflecting water needs of the plant material.
  - The maximum water a water purveyor or regulatory authority will provide or allow or any arbitrary value intended to conserve water; AF could be 0.7, 0.8, etc.
  - More than one adjustment factor may be employed where plant-water requirements and regulatory or conservation demands must both be considered. Water shortage response: 0.5–0.6.
LA = area of the irrigated landscape \( \text{ft}^2 \)
0.623 = conversion factor to convert inches to gallons of water.
LF = leaching factor (optional), greater than 1.0 based on water quality and soil type. This is an optional multiplier used in cases of poor water quality (i.e., recycled, surface, or brackish sources).

3.2 Landscape water requirement
a. The landscape water requirement is determined by summing the water requirement for each type of hydrozone in the landscape:

\[
\text{LWR} = \text{WR}_{H1} + \text{WR}_{H2} + \text{WR}_{H3} + \text{etc.}
\]

where

- LWR = landscape water requirement \{gallons\}
- WR_{H1} = hydrozone water requirement

b. Estimating the water requirement of a hydrozone uses the following information:

\[
\text{WR}_{H} = \left( \text{ET}_0 \times \text{PF} \right) - \text{Re} \times \text{LA} \times 0.623 \times \text{IE}
\]

where

- WR_{H} = hydrozone water requirement \{gallons\}
- ET_0 = evapotranspiration for the time period \{in.\}
- PF = plant factor or turfgrass factor for the hydrozone
- Re = rainfall that is effective within the root zone
- LA = landscape area \{ft^2\}
- 0.623 = conversion factor to gallons
- IE = irrigation efficiency multiplier — includes system, application, management, and scheduling efficiency (not distribution uniformity); the expected efficiency range is 1.11 to 1.54.
  - multiplier of 1.11 approximates 90 percent efficiency
  - multiplier of 1.25 approximates 80 percent efficiency
  - multiplier of 1.33 approximates 75 percent efficiency
  - multiplier of 1.54 approximates 65 percent efficiency

c. Recommendations

1) An additional amount of water will be needed to leach any salt accumulation as explained in the water budget above.

2) Determine how to maximize the benefit of rainfall to reduce irrigation water.

3) If the site has multiple water sources then the total water budget may need to be allocated to divide among them.
4. **Scheduling**

Scheduling landscape irrigation is a process that requires knowledge of the irrigation system’s performance characteristics (application rate, distribution uniformity, etc.), soil type and soil water properties, plant root depth, and plant water requirements to determine when and how much water should be replaced. The irrigation schedule is dynamic. It is influenced by rainfall events and seasonal weather patterns. Aspects of irrigation scheduling to maximize efficiency and effectiveness include: total run time for each zone, dividing total run times into multiple cycle-start programs to eliminate or minimize runoff, and the frequency of watering events to minimize plant-water stress. Schedules can be simple single program configurations or more complex multiple programs running stacked in sequence or overlapped running concurrently. The irrigation manager must understand the capabilities of the irrigation system, the soil and soil water properties, average root zone depth, solar exposure, the intended purpose and function of the landscape, and the plant water requirements in order to properly determine an irrigation schedule.

Technologies are available that monitor weather or soil moisture conditions and auto-adjust schedules based on factors that the manager enters into the controller. These controllers can operate with manual schedule adjustments, by percentage of preprogrammed watering times that are based on observed weather changes, or by input from weather, soil moisture, or flow sensors.

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**Irrigation Effectiveness**

*Irrigation efficiency* is irrigation water beneficially used compared to the amount of irrigation water applied or supplied to the site and is expressed as a percentage.

*Distribution uniformity* is not a measure of efficiency but rather a way to characterize the evenness of application of water to the planted area and is expressed as a decimal value. In landscape irrigation, this has greatest importance in turfgrass areas.

*Irrigation Effectiveness* is achieved when the plant water requirement has been supplied without runoff or deep percolation. High distribution uniformity is essential to applying the least amount of water to meet the plant water requirements. Irrigation scheduling is applying the right amount of water at the right time to maintain a healthy landscape.

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4.1 **Communication**

a. Determine if there are any constraints regarding time of day or day week for irrigation.
   1) Use of the site (such as sporting events, mowing schedule etc.).
   2) Watering restrictions in place by water purveyor.

b. Expectations for landscape appearance and water conservation potential.
   1) What is the intended level of aesthetic acceptance (stress level)?

c. Desired benefits
   1) Water use efficiency
2) Runoff reduction
3) A more robust plant health
4) Sound root system
5) Reduce weed, disease, and other pest problems

### 4.2 Documentation

a. If not assigned, determine an appropriate water window for irrigation.
b. Utilize information from site evaluation to be used for scheduling (See Site Evaluation).

### 4.3 Action

a. Create an irrigation schedule.

1) How much water to apply?
   - Based on weather data and calculated plant water requirement since last irrigation or rainfall.
   - Based on allowed soil moisture depletion.
   - Based on the soil’s ability to move water by capillarity.
   - Account for rainfall effectiveness.
   - Does it fit within the landscape water allowance?

2) How long are the runtimes?
   - Total run time is based on the application rate of the irrigation equipment.
   - Use multiple cycle-starts to prevent runoff.
     (i) Based on soil type, amount of organic matter present and compaction.
     (ii) Consider slope and compaction issues.
     (iii) Application rate of the equipment.
     (iv) As a rule of thumb when observing runoff, reduce subsequent cycles by 20 percent.

1. Some irrigation equipment has a minimum amount of run time required to effectively apply water to all of the area.
2. Site observations of runoff collected during evaluation activities provides valuable information to use for calculating cycle-soak scheduling.
   - Does the irrigation schedule fit within the watering window?
     (i) Comply with time of day watering.

3) How often to irrigate?
   - Best practice is to irrigate when soil moisture has been depleted to a predetermined threshold that does not contribute to unplanned plant stress.
     (i) Run times remain constant, but the interval between irrigation days changes.
   - Regular interval or designated days of the week.
     (i) The irrigation days are constant but the run time changes to match the amount of water extracted by the plants usually based on modified ET information.
   - Comply with any mandatory watering restrictions for day or days of the week.

4) Special considerations
• Incorporate personal experience of managing the site with the calculated schedules to assure water use effectiveness.
• If water sources have high salts, additional irrigation events are needed to flush the harmful salts out of the root zone.
  (i) Recommendation
    1. The use of soil moisture sensor systems and rain sensors as bypass devices can assist in scheduling (in arid, temperate, and humid regions).

b. Program the controller
   1) Understand the features of the controller to facilitate scheduling and management.
   2) If using smart controller technologies, program the controller with site-specific information such as soils, plant type, irrigation performance, etc.
   3) Set inputs to on-site sensors such as rain shutoff devices, soil moisture sensors, wind sensors, or freeze sensors to inhibit irrigation when it is not conducive for effectiveness.

4.4 Recommendations
  a. Research and utilize irrigation scheduling programs that fit needs.
  b. Create a method to adjust irrigation schedules quickly and appropriately.
  c. Compare proposed schedule with current schedule (feedback loop) with the original designer/company, where possible.

5. Monitoring
The water manager measures water usage and compares it to the estimated water requirement based on current weather conditions. The water manager assesses the overall landscape health and appearance to determine if irrigation is effective. The manager makes adjustments to the irrigation schedule as needed to respond to current conditions including responding to drought or water shortages. The information collected during ongoing monitoring provides the data to communicate with interested parties and provides the basis for scheduling refinements.

5.1 Communication
  a. Are the expectations realistic for what’s available (resources, money, water, personnel, restrictions and ordinances, etc.)?
  b. Water budget comparison feedback loop.
     1) Is the water being used within the expected water budget?
     2) Is the water budget realistic and/or flexible? If the water budget is static, modifications to expectations or management may need to vary.
  c. If there are drought or water shortages, is the site adapting in accordance with the contingency plan?
5.2 Documentation
   a. Obtain past water use records.
      1) Three years of historical usage is recommended.
   b. Obtain past weather data.
      1) Use local or nearby weather and ET data from a reliable source.
         • There are many sources of weather information; real time is recommended.
         • Monitor drought conditions.
   c. If using on-site harvested or collected water sources.
      1) Document current water levels in storage tanks.
      2) Water test reports
         • Safety of the water — protect people
         • Quality of the water — protect plants
      3) Observe changes to water supply and pressure including pump station functionality.

5.3 Measurement
   a. Record water usage.
      1) Monitor water usage frequently and at regular intervals.
         • Read meters on a regular basis (at least monthly during growing season).
         • If meters are not available, measure applied irrigation water using precipitation gauges in the irrigated area.
   b. Monitor and record on-site rainfall.
   c. Monitor soil conditions and root zone.
      1) Record soil moisture based on soil core sample or sensor reading.
      2) Measure soil compaction with an infiltrometer or similar tool.
      3) Verify root zone depth and soil conditions.
      4) Does the amount of soil moisture within the root zone concur with the expectations?

5.4 Action
   a. Observe plant health and record problems identified.
      1) Stress — signs of underwatering
         • Identify indicator plants
      2) Ponding — signs of saturated soils caused by too much water
      3) Weeds, diseases, and pests
   b. Compare calculated water need to water applied to refine your schedule.
   c. Compare current water usage using real-time weather data to historical water usage.
   d. Develop a soil moisture balance sheet to maximize beneficial rainfall.
   e. As plant material matures or changes to the landscape occur, ensure that system modifications are implemented by following the Landscape Irrigation Best Management Practices PG1 (design) and PG2 (installation).
      1) Ensure that system modifications are in response to changing site conditions.
2) In accordance with any applicable local codes or mandates.

5.5 Recommendation
a. Install a dedicated irrigation meter to improve management capability.
b. Explore new technology for monitoring soil conditions and root zone conditions.

6. Site evaluation
An evaluation is a (periodic) review of system performance resulting in adaptive management and initiates recommendations for scheduling, maintenance and monitoring. The irrigation manager inspects the irrigation system to verify that system maintenance procedures are being followed, that equipment is working optimally and that landscape plantings are properly considered when scheduling irrigation. A review of system performance assists the irrigation water manager, owner or end-user to develop an effective irrigation water management plan.

A site evaluation will also forecast requirements for a maturing landscape and assess whether the system in its’ present configuration will continue to meet the overall objectives of the site.

An Audit by Another Name
There are variations in the levels of detail when observing a site and system performance. Often the terms are used synonymously, but they can actually mean different things:

- System review or assessment or inspection — visual inspection to verify equipment functionality (“wet check”).
- Site survey — visual inspection to verify equipment functionality, runoff, and observe landscape health.
- Irrigation audit — visual inspection of system with a catch can test(s) to measure performance, following the IA has audit guidelines. ASABE standard (S626) is in development.
- Site evaluation — comprehensive visual inspection of system, landscape, and soil, along with a catch can test to measure system performance, runoff and landscape function and health.

6.1 Communication
a. Establish the goal and purpose of performing a system evaluation.
b. Share the irrigation system performance results.
c. Make recommendations on changes that might be needed.

6.2 Documentation
a. Water supply
   1) Source(s) (potable, groundwater, rainwater catchment, recycled, etc.)
   2) Expected reliability and availability of alternate water sources.
3) Verify that backflow prevention has been tested and conforms to code.

b. Soils
   1) Texture (sandy, loamy, clayey).
   2) Preliminary estimate of water holding capacity/infiltration rate.
   3) Examine soil profile of the root zone.
   4) Measure depth of root zone.

c. Landscape
   1) List of plant types/turf types.
   2) Assess condition of plants — by species and by hydrozone.

d. Review existing irrigation system.
   1) Sprinkler/drip type used in system.
   2) Identify hydrozones.
      • Visual inspection of how well system is operating.
         (i) Patterns
         (ii) Wet/dry spots
         (iii) Poor plant health
         (iv) Overall level of system maintenance.
      • Do irrigation system zones conform to identified hydrozones?

6.3 Measurement
a. Water supply
   1) Quality of water (ph, salinity, hardness, etc.)
   2) Quantity (available gpm)
b. Soils
   1) Drainage or compaction problems.
   2) Consistency of soil type throughout the site.
c. Landscape
   1) Determine water requirement for each plant type.
   2) Measure hydrozone area.
   3) Identify sloped areas.
d. Review existing irrigation system
   1) Consistency in sprinkler type/nozzle and spacing within a zone.
      • Estimated precipitation rate.
      • Estimated distribution uniformity.
      • Recommend catch can test as needed.

6.4 Action
a. Draw conclusions based on:
   1) Soils/drainage/compaction issues.
   2) Irrigation design issues.
      • Improper hydrozones
• Improper pressure
• Poor coverage
• Overspray
3) Landscape issues.
4) Improper plant usage.
5) Mixed hydrozones.
6) Water quality issues.
7) System maintenance issues including age of components.
8) System functionality issues.
• Limited programming capacity, lack of sensors, etc.
9) System management issue.
• How well are the system and its components being utilized?
b. Recommendations based on:
   1) Most critical issues that need to be addressed.
   2) Return on investment when implementing recommendations.

6.5 Communication feedback
a. Accountability
   1) Owner
      • Final/financial decision maker
   2) Water manager
      • Develops irrigation schedule/program
      • Develops maintenance tasks and intervals
   3) Maintenance personnel

6.6 Recommendations
a. Create a maintenance routine including documenting inspections completed.
b. Assess plant material functionality and or placement within hydrozone.
c. Suggest the use of technologies which will help reduce water use and improve irrigation management.
KEY REFERENCES

1. Source references

1.1 *Irrigation, Sixth Edition*. 2011. Irrigation Association, Fall Church, VA.
1.2 *Landscape Irrigation Auditor, 3rd Edition*. 2013. Irrigation Association, Falls Church, VA.
1.3 EPA WaterSense
   Refer to the irrigation products and outdoor pages web site at
   http://www.epa.gov/watersense/.
1.4 Source of local historical or current evapotranspiration (ET<sub>c</sub>) data (if available).
   Refer to the “ET Connection” on the Irrigation Association’s web site at
   http://www.灌溉.org/.
1.5 Soils data USDA Natural Resource Conservation Service (NCRS) http://www.nrcs.org
1.6 Climate Data http://www.ncdc.noaa.gov/
1.7 Subsurface Drip Irrigation Systems (SDI) Water Quality Assessment Guidelines, Kansas State
   University, July 2003
## Appendix A – Stakeholders and Issues related to water

### Table A-1

<table>
<thead>
<tr>
<th>STAKEHOLDERS</th>
<th>RESPONSIBILITIES RELATED TO WATER CONSERVATION AND MANAGEMENT</th>
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</table>
| Water Purveyor | • Documenting beneficial and reasonable uses of water  
                  • Promoting the adoption and use of reclaimed water  
                  • Pricing water to recognize its limited nature (the pricing mechanism should provide incentives to water users who conserve water and penalties for those who waste it)  
                  • Establishment of educational programs and materials for users of irrigation systems  
                  • Establishing incentives to promote efficient irrigation systems  
                  • Maintaining desired water pressure in mains and submains  
                  • Using and maintaining water meters  
                  • Reducing chemical movements  
                  • Reducing runoff or off-target irrigation |
| Irrigation Designer, Consultant, or Engineer  
Irrigation Contractor or Installer  
Maintenance Contractor  
Owner or End-user of Irrigation System  
Landscape Contractor  
Water Purveyor | 1. Assure overall quality of the irrigation system  
2. Design the irrigation system for the efficient and uniform distribution of water  
3. Install the irrigation system to meet the design criteria  
4. Maintain the irrigation system for optimum performance  
5. Manage the irrigation system to respond to the changing need for water in the landscape  
6. Maintaining healthy turf and landscape plants during droughts  
7. Reducing runoff or off-target irrigation |
| Landscape Contractor  
Nursery and Landscape Retail/Wholesale Companies | 1. Optimum turf and landscape fertilizing  
2. Reduction of biomass  
3. Informing owners about water efficient landscape practices |
| Nursery and Landscape Retail/Wholesale Companies | 1. Characterizing plants for less water use, native plants and xeriscape plants  
2. Identifying turf species that use less water |
### Appendix A

#### Table A-2

State, Federal and Public Agencies

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<tr>
<th>AGENCY</th>
<th>RESPONSIBILITIES RELATED TO WATER CONSERVATION AND MANAGEMENT</th>
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</table>
| State, Federal and Public Agencies (General) | 1. Policies that allow for the lease, sale or transfer of established water or water rights without jeopardizing established water rights  
2. Establishment of an independent entity to institute studies to identify water use and misuse by all segments of the water-using industry and to provide data on which to base decisions regarding equitable water distribution during periods of water shortage  
3. Watershed protection (hydrology)  
4. Integrating water agency involvement in land use planning  
5. Reducing runoff or off-target irrigation  
6. Reducing chemical movements  
7. Optimizing turf and landscape fertilizing  
8. Reducing and managing grass clippings  
9. Maintaining healthy turf and landscape plants during droughts |
| State and Federal Environmental Regulatory Agencies | • Nonpoint source pollution of water resources  
• Water and water quality information  
• Regulations for using treated effluents  
• Information on reference evapotranspiration |
| Public Agencies (Parks) | 1. Maintaining public irrigation systems  
2. Monitoring of irrigation systems and water usage  
3. Maintaining irrigation system inventory |
| Municipal and Rural Water Departments and Companies | 1. Collaboration with the green industry to establish appropriate landscape water allowance adjustment factors  
2. Insuring adequate water supplies to meet demands  
3. Regulating and enforcing local regulations |
| State Water Use Permitting Agencies | 1. Documenting and planning for future water needs  
2. Equitably appropriating water rights  
3. Registering professional engineers, licensed irrigation designers, consultants, landscape architects, and contractors  
4. Coordinating continuing education programs |
| Higher Education, Universities, Federal Research Agencies | 1. Irrigation curricula, agronomic, horticulture, and landscape architecture education/research/extension  
2. Irrigation technology, crop varieties, irrigation management, water quality research  
3. System modeling and simulation |
| Federal Conservation Agencies | 1. Training, demonstrations, technological expertise  
2. Sustaining and protecting natural resources  
3. Coordinating local conservation district programs |